EFFECT OF PLACEMENT OF UREA FERTILIZER ON THE YIELD OF WHEAT

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CERTIFICATE

This is to certify that the thesis entitled, "*EFFECT OF PLACEMENT OF UREA FERTILIZER ON THE YIELD OF WHEAT*" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY, embodies the result of a piece of *bona fide* research work carried out by **MD. FAIJUL ALAM SIDDIK, Reg. No. 04-01222** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: 16/1/11

Place: Dhaka, Bangladesh

(Prof. Dr. Md. Fazlul Karim)

Supervisor


DEDICATED TO
MY
BELOVED PARENTS

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ACRONYMS

%	=	Percentage
AEZ	=	Agro- Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
BCUSG	=	Bitumen-Coated Urea Super granules
BCU	=	Bitumen-Coated Urea
cm	=	Centi-meter
cv.	=	Cultivar (s)
CV (%)	=	Percentage of Coefficient of Variance
^0C	=	Degree Celcius
DAS	=	Days After Sowing
et al.	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	gram (s)
ha	=	Hectare
HI	=	Harvest Index
Hr	=	hour (s)
kg	=	Kilogram
LSD	=	Least Significant Difference
m	=	Meter
Mm	=	Millimeter
MP	=	Muriate of Potash
m^2	=	Square meter
MRPU	=	Mussoorie rock phosphate urea
N	=	Nitrogen
No.	=	Number
NS	=	Not significant

PU	=	Prilled Urea
SAU	=	Sher-e-Bangla Agricultural University
t ha^{-1}	=	Tons per hectare
TSP	=	Tripple Super Phosphate
UNDP	=	United Nations Development Program
USG	=	Urea Super Granule
var.	=	Variety

EFFECT OF PLACEMENT OF UREA FERTILIZER ON THE YIELD OF WHEAT

ABSTRACT

The experiment was carried out at the research field of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, during November 2008 to March 2009 to study the response of wheat to urea fertilizer placement. The treatment consisted of T_1 = Prilled urea broadcasted, T_2 = Prilled urea placed in furrow, T_3 = Prilled urea placed between two rows of wheat, T_4 = Prilled urea + seed in furrow, T_5 = Line sown seed + line placed Prilled urea, T_6 = Line sown seed + Prilled urea given on soil of furrow, T_7 = Wheat seeds + urea super granule (USG) in the same furrow at 8 cm distance, T_8 = USG placed in between two wheat lines at 8 cm distance. The experiment was set up in a randomized complete block design (RCB) with three replications. Placement of urea had significant effect on plant height, tillers plant^{-1}, above ground dry matter plant^{-1}, length of spike, spikelet spike^{-1}, 1000 grain weight, grain yield ha^{-1}, biological yield and harvest index of wheat. The highest grain yield (3.11 t ha^{-1}) of wheat was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment which indicates the superiority of urea super granules over prilled urea and the lowest grain yield (2.43 t ha^{-1}) from T_4 (Prilled urea + seed in furrow) treatment. Lower straw yield from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment indicated maximum partitioned of dry matter towards seed as reflected with higher value of harvest index (41.80%). The highest gross return (Tk. 553109) ha^{-1}, net return (Tk. 10624) ha^{-1} and benefit cost ratio (1.24) were also obtained from T_8 treatment. The second highest benefit cost ratio of 1.16 was obtained from T_7 (Wheat seeds + urea super granule in the same furrow at 8 cm distance) treatment. The lowest benefit cost ratio (1.02) was obtained from T_3 (Prilled urea placed between two rows of wheat) and T_4 (Prilled urea + seed in furrow) treatments. The result of the experiment thus indicated that placement of USG in between two wheat rows at 8cm distance was superior method followed by prilled urea placement in between two rows of wheat and prilled urea + seed in furrows.

Chapter 1
Introduction

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the succeeding alternative cereal crop of Bangladesh afterward to rice. It ranks 1st in respect of total production in the world. Thereabouts one third population of the world use wheat as their staple food (Hunshell and Malik, 1983). It contains superior protein than rice. Wheat is one of the most important staple food crops of the world, occupying 17% (one sixth) of crop acreage worldwide, feeding about 40% (nearly half) of the world population and providing 20% (one fifth) of total food calories and protein in human nutrition (Gupta *et al*., 2008).

Rice exclusively cannot fulfill the cereal necessity. Wheat is the second substantial cereal crop in Bangladesh. Consequently, efforts are being made to increase the production of wheat. Sum up land acreage of wheat in Bangladesh was 394.6 thousand hectares and the total production was 849 thousand metric tons with an average yield of 2.15 t ha^{-1} in 2008-2009 (BBS, 2009). Wheat is well adapted to our climate and can play a indispensable role in reducing our food shortage.

Wheat seed contains plenty of proteins (12.6%), vitamins (B1, B2, B3, and E) and minerals (folic acid, calcium, phosphorus, zinc, copper, iron). As a second cereal crop, its importance is high in Bangladesh and increasing day by day. In Bangladesh, wheat is grown primarily as a rainfed crop in the post monsoon winter (November - March). The monthly maximum and minimum air temperature during this period ranges from 25.8 to 30.5°C and 13.8 to 20.3°C in the south east zone and from 24.9 to 32.3°C and 10.3 to 16.7°C in the north east zone respectively (Hossain *et al*., 2001).

Urea (prilled urea) is widely used in the agricultural industry as an animal feed additive and fertilizer with 46% nitrogen. It is an efficacious fountain of nitrogen fertilizers. Urea is water soluble white crystalline solid organic compound. It has the chemical formula of $CO(NH_2)_2$.

Prilled urea or prills are formed by dropping liquid urea from a prilling tower into droplets that dry into roughly spherical shapes 1mm to 4mm in diameter where as granular urea is slightly larger and harder.

Globally, fertilizer nitrogen (N) applications are approximately 80 million tonnes, with half being applied in developing countries and the other half in developed countries (FAO, 1990). It has been estimated that by the year 2025 the consumption of nitrogen fertilizer will increase 60 to 90 percent, with two-thirds of this being applied in the developing world (Galloway *et al.*, 1995). This inclination in fertilizer use is mostly driven by the need of developing countries to keep food supply up with population growth. It has been projected that by the year 2020 world population will be more than 8 billion people, with more than 90 percent of this additional growth concentrated in developing countries (Sadik, 1992). Most of the irrigated spring wheat in the world is located in developing countries. These areas have high yield potential and high levels of input use contrasted to other wheat-producing regions in the developing world. The International Maize and Wheat Improvement Center (CIMMYT) has defined the wheat irrigated areas as mega-environment one (ME1) which includes the Indo-Gangetic plains in India and Pakistan, the Nile River Valley in Egypt and the Yaqui Valley in Mexico among others (Rajaram *et al.*, 1993). These areas already produce 42 percent of the wheat in developing countries, and it is likely that further intensification will take place in order to keep up with food demand. However, the efficiency of N fertilizer use tends to be low in these systems (Byerlee and Siddiq, 1994), and further intensification with current agronomic practices will likely lead to higher inefficiencies and `therefore higher N losses. The nitrogen that is lost, in addition to being an expense to the farmers, also has an environmental cost. It has been documented that land conversion and intensification alter the biotic interaction and patterns of resource availability in ecosystems and can have serious local, regional and global environmental consequences (Matson *et al.*, 1997). Accordingly, it is important to identify nitrogen management practices that will allow meeting the increasing claim for food and fibre while diminishing environmental impact and being economically seductive to farmers.

Nitrogen is a very momentous element for crop cultivation but highly deficient in most soils of Bangladesh. Bangladeshi farmers are mainly using urea, the most available source of nitrogen and broadcasting it on the soil surface. It is highly water-soluble and a quick release fertilizer. For this reason, its application to the soil surface may result in a significant loss as ammonia to the atmosphere by volatilization and also by leaching through soil profile, thus, reducing the efficiency of urea which ultimately results in poor yield. Khalil *et al.* (1996) stated that nitrogen use efficiency is only 38.84 and 38.14% with using 120 and 180 kg Nha^{-1}, respectively in wheat.

Granular nitrogen like urea super granules (USG) a slow releasing fertilizer, is being marketed as an N source instead of conventional prilled urea. The International Fertilizer Development Center (IFDC), have conclusively demonstrated that compacted USG, that is, urea with 1–3 g granules, are an effective N source (Savant *et al.*, 1990). In general, one or more USG are deep placed (7–10 cm depth) by hand at the center of every four rice seedling hills in rice soils during or after rice transplanting. Savant and Stangel, 1998 have shown that N loss is significantly reduced by the use of USG, which results in a significant increase in rice grain yield under flooded conditions compared with split applied PU.

Wheat is a *rabi* crop. During *rabi* season our farmers are concerned to grow boro rice and maize as their yield is higher than wheat. Wheat has been pushed down to the marginal land due to the increased area of boro rice and maize. Thus we obtain poor yield from wheat. It is very urgent to meliorate wheat yield with high yielding variety cultivating on the main land. The solely way is to bring back wheat on the main land with high yield potentiality through different managements of fertilizers like urea. With all these fact under consideration the present study was under taken with following objectives:

(1) To study the effect of placement of urea fertilizer on the growth and yield of wheat.

(2) To validate the findings of nitrogen management from economic point of view.

Chapter 2
Review of Literature

REVIEW OF LITERATURE

Urea is the most frequently used as Nitrogen fertilizer globally. Urea can be applied in different ways. In Bangladesh crystal urea is applied mostly as top dressing. But top dressing sometimes induces imbalance in yield components and decreases yield. It was observed that urea super granules (USG) can minimize the loss of N from soil and hence the affectivity increased up to 20-25% (Hasanuzzaman *et al*., 2009).

Nitrogen fertilizer when applied as USG was reported to have increased grain yield by around 18% and saved around 32% N in wetland rice over prilled urea and appeared to be a good alternative N fertilizer management for rice production (Anon., 2004).

Hasan *et al.* (2002) determined the response of hybrid (Sonar Bangla-l and Alok 6201) and inbred (BRRI Dhan 34) rice varieties to the application methods of urea super granules (USG) and prilled urea (PU) and reported that the effect of application method of USG and PU was not significant in respect of panicle length, number of unfilled grains panicle^{-1} and 1000-grains weight.

Haque (2002) reported that application of fertilizers greatly increased tuber yields of potato and point placement of USG further boosted up the yield of potato tubers.

Miah and Ahmed (2002) conducted an experiment and found that deep placement of urea super granules (USG) has been proven to improve N efficiency. In terms of N recovery, agronomical and physiological efficiency, rice varieties utilized N more efficiently when applied as super granules in deep placement.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea super granules (USG) and broadcasting prilled urea (PU) as sources of N in T. aman rice. USG and PU were applied @ 40, 80, 120 or 160 Kg N ha^{-1}. They reported that USG was more efficient than PU irrespective of nitrogen level in producing panicle length, filled grains panicle^{-1} and 1000-grain weight.

Mishra *et al.* (2000) conducted a field experiment during 1994-95 in Bhubaneswar, Orissa, India and reported that USG @ 76 kg N ha^{-1} application at 0, 7, 14 for 21 DAT increased plant height.

Ahmed *et al.* (2000) also found that USG was more efficient than PU irrespective of nitrogen levels in producing yield components, grain and straw yields of aman rice. Placement of USG @ 160 Kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of N.

Balaswamy (1999) found that in an experiment deep placement of nitrogen as urea super granules reduced the weight of weeds resulting in more panicles and filled grains and also increased the grain yield of rice over the split application of prilled urea by 0.43 and 0.3 t ha^{-1} and basal application of large granular urea by 0.73 and 0.64 t ha^{-1} in 1985 and 1986, respectively.

Department of Agricultural Extension conducted 432 demonstrations in 72 Upazilla of 31 districts in Bangladesh during 1996-97 winter season of (Boro rice) and reported that USG plots, on an avenge, produced nearly 5 percent higher yields than the PU treated plots while applying 30-40% less urea in the form of USG (Islam and Black, 1998).

Vijaya and Subbaiah (1997) showed that plant height of rice increased with the application of USG and were greater with the deep placement method of application both N and P compared with broadcasting.

Singh and Singh (1997) conducted a field experiment during 1987 in Uttar Pradesh, India. Dwarf rice cv. Jaya was given 90 or 120 kg N ha^{-1} as urea super granules, large granular urea or neem cake coated urea. N was applied basally, or in 2 equal splits (basally and panicle initiation). They found that grain yield was highest with 120 kg N (4.65 ha^{-1}), was not affected by N source and was higher with split application.

Kumar *et al.* (1996) reported that application of USG in the sub soil gave 22% higher grain yield of rice than control.

Khalil *et al.* (1996) stated that nitrogen use efficiency was only 38.84 and 38.14% with using 120 and 180 kg N/ha as prilled urea, respectively in wheat.

Miah *et al.* (2004) found that LAI was significantly higher in USG receiving plots than urea at heading and the total dry matter production was affected significantly by the forms of N fertilizer. USG applied plots gave higher TDM compared to urea irrespective of number of seedling transplanted $hill^{-1}$. At the same time it also noticed that the difference between treatments for TDM was narrower at early growth stages but became larger in later stages.

Rashid *et al.* (1996) conducted field experiments in two locations of Gazipur district during boro season (Jan-May) of 1989 to determine the nitrogen use efficiency of urea super granules (USG) and prilled urea (PU) in irrigated rice cultivation. They reported that 87 kg N ha^{-1} from USG produced the highest grain yield followed 58 kg N ha^{-1} from USG and 87 kg N ha^{-1} from PU.

Das and Singh (1994) pointed out that the grain yield of rice cv. RTH-2 during Kharif season was greater for deep placed USG than USG for broadcast and incorporated or three split applications of PU. Mishra *et al.* (1994) conducted a field trial with rice cv. Sita giving 0 or 80 kg N ha^{-1} as urea, urea super granules, neem coated urea. They reported that the highest grain 3.39 t ha^{-1} was obtained by urea in three split applications.

Bhale and Salunke (1993) conducted a field trial to study the response of upland irrigated rice to nitrogen applied through urea and USG. They found that grain yield increased up to 120 kg urea and 100 kg USG.

Bhardwaj and Singh (1993) observed that placement of 84 kg N as USG produced a grain yield t ha^{-1} which was similar to placing 112 kg USG and significantly greater than nitrogen sources and rates.

Singh *et al.* (1993) pointed out that application of 30 or 60 kg N ha^{-1} as PU or USG gave the highest grain yield and N uptake increase with the rate of N application and were highest with deep placed USG. N use efficiency was the highest with 30 Kg N ha^{-1} from deep placed USG. Zaman *et al.* (1993) conducted two experiments on a coastal saline soil at the Bangladesh Rice Research Institute (BRRI), Regional station, Sonagazi in Aus season of 1988 and 1989 to compare the efficiencies of prilled urea (PU) and urea super granules (USG) as sources of N for upland rice. The N doses used as treatments were 29 kg ha^{-1} and 58 Kg ha^{-1} for both PU and USG. The test variety was BR-20. They found that USG consistently produced significantly higher grain yield and straw yield than PU.

It was reported that the grain yield of millet was the highest with Bitumen-Coated Urea Super granules (BCUSG) and the lowest with urea and in case of wheat, among N sources residual effects were in the order BCUSG> USG>BCU> urea (Sarker and Faroda, 1993).

Modified urea materials under different moisture regimes influence NH_3 volatilization loss and significantly less NH_3-N loss was observed for USG treatments than from surface applied urea (Muneshwar *et al.*, 1992).

Roy *et al.* (1991) compared deep placement of urea super granules (USG) by hand and machine and prilled urea (PU) by 2 to 3 split applications in rainfed rice during 1986 and

1987. They reported that USG performed better than PU in all the parameters tested. Filled grains panicle^{-1} was significantly identical with USG and PU three split treated plots with the highest from PU three split treated plots. Significant difference was observed in 1000-grain weight and highest grain weight was obtained from USG (by hand) treated plots.

Thakur (l991a) observed that yield attributes differed significantly due to levels and sources of nitrogen application of 60 kg N ha^{-1} through USG produced the highest panicle weight, number of grains panicle^{-1}, and 1000- grain weight.

Sen and Pandey (1990) carried out a field trial to study the effects of placement of USG (5, 10 or 15 cm deep) or broadcast PU @ 38.32 kg N ha^{-1} on rice of tall long duration Mashuri and dwaf, short duration Mashuri. They reported that all depths of USG placement resulted in higher yield characters than broadcast PU; however, differences except for panicle lengths were not significant.

The proper placement of fertilizer can also increase its use efficiency as reported by Eriksson (1990).

Rekhi *et al.* (1989) conducted an experiment on a sandy loamy soil with rice cv. PR 106 providing 0, 37.5 or 75 or 112.5kg N ha^{-1} as 15 N-labeled PU or USC. They noted that application of PU produced the highest plant height.

Mirzeo and Reddy (1989) worked with different modified urea material and levels of N @ 30, 60 and 90 Kg ha^{-1}. They reported placement of USG in root zone produced the highest number of tillers at 30 and 60 days after transplanting (DAT).

Das (1989) reported that the dry matter yield of rice were higher with application of USG of various forms and methods of application of N fertilizers to rice grown under flooded conditions. Placement of N as USG (1 and 2 g size) in the root zone at transplanting was the most effective in increasing dry mater production and were the lowest with urea applied as a basal drilling (Rambabu *et al.* 1983).

Jee and Mahapatra (1989) observed that number of effective tillers m^{-2} were significantly higher with 90 kg N ha^{-1} as deep placed USG than split application of urea. Rama *et al.* (1983) mentioned that the number of panicles m^{-2} increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as different modified urea materials and USU produced significantly higher number of panicles 12 m^{-2} than split application of PU.

Rymar *et al.* (1989) reported that slow release fertilizers (N as encapsulated urea, granular oxamide and oxamide powder) were more effective than the conventional fertilizers (ammonium sulphate or urea).

Haque, (1998) reported that urea super granule point placement in rice has been found to be a good practice for poor farmer. It can reduce loss of urea-N and improve its efficiency by more than 60% in flooded rice with a surplus of about 15-20% rice yield over conventional urea broadcast application.

Presently, urea super granule is a proven concept for use in rice production. (Diamond, 1988; Kumar *et al.*, 1989; Savant and Stangel, 1990)

In a field trial, Sarder *et al.* (1988) found that, 94.8 kg N ha^{-1} as basal application of USG gave longer panicle and total number of filled grains penicle^{-1} than the other N sources.

Singh and Singh (1986) worked with different levels of nitrogen as USG, sulphur coated and PU @ 27, 54 and 87 kg ha^{-1} . They reported that deep placement of USG resulted in the highest plant height than PU. They also reported that the number of tillers m^{-2} was significantly greater in USG than PU in all levels of nitrogen.

Nayak *et al.* (1986) carried out an experiment under rainfed low land conditions with the amount of 58 kg N ha^{-1} as USG placed in root zone. They reported that USG was significantly superior to as sulphur coated urea (SCU) or applying in split dressing, increasing panicle production $unit^{-1}$ area.

Rajagopalan and Palanisamy (1985) found that 75 kg ha N as USG gave the tallest plant (83 cm). Evaluation of rice program during 1975 to 78 showed that deep placement of USG is an effective means of increasing rice yields compared with traditional split application of PU (Craswell and De Datta, 1980).

Broadcast application of urea on the surface soil causes loss upto 50% but point placement of USG in 10 cm depth can save 30% nitrogen over prilled urea, increase absorption rate, improve soil health and ultimately increase rice yield (Savant *et al.*, 1991, Creswell and De Datta 1980).

The N uptake and recovery of applied N were the highest in the USG + urea treatment and N use efficiency was highest with urea alone (Saha,1984). In a field experiment, wheat grain yield increased with increasing residual N rate and was highest after deep placement of 120 kg N as USG (Das and Singh, 1994).

From reviewing the findings it is imperative to use super granuler urea to crop cultivation for higher yield with saving urea cost and minimizing pollution of environment.

Chapter 3
Materials and Methods

MATERIALS AND METHODS

3.1 Location

The experiment was carried out at the experimental farm of the Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh, during the period from November 2008 to March 2009.

3.2 Site selection

The experimental field was located at $90^{\circ} 22'$ E longitude and $23^{0} 41'$ N latitude at an altitude of 8.6 meters above the sea level. The land was located at AgroEcological Zone 28 of "Madhupur Tract"(Appendix I). It was deep Red Brown Terrace Soil and belongs to "Nodda" cultivated series. The soil was clay loam in texture having P^{H} ranges from 5.47 to 5.63. Organic matter content was very low (0.82%).

3.3 Climate and weather

The climate is subtropical with low temperature and minimum rainfall during December to March was the main feature of the rabi season.

3.4 Planting materials

Wheat (*Triticum aestivum*) was used in this experiment.

3.5 Plant characteristics and variety

BARI Gom-19 (Shourav) is a high yielding variety of wheat. The variety was released by WRC (Wheat Research Centre) of BARI in 1998. This variety is suitable for late sowing. It completes its life cycle within 102-110 days. The height of the plant is 90-100 cm. It produces 5-6 tillers plant^{-1}. The stem is hard enough and does not lodge in wind and storm. Leaves are flat, droopy and deep green. Flag leaf is wide and droopy in nature. The number of spikelet spike^{-1} is 42 - 48 and size of grains are medium to large and the color of the grains is white. The weight of 1000 grain is 40-45g. Plant requires 60-70 days to emerge spike. It has ability to give 3.5-4.6 t grain yield ha^{-1} in favorable condition. This variety is tolerant to leaf spot and leaf rust diseases. This variety is heat tolerant that is why it gives better yield under late sown condition. The variety gives 10-12% more yield than the traditional ones (BARI, 2005).

3.6 Granular urea

The weight of urea super granules (USG) was 1.8 g/granule.

3.7 Experimental treatments

Treatments were:

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance.

3.8 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental unit was divided into three blocks each of which represents a replication. Each block was divided into 8 plots in which treatments were applied at random. The distance maintained between two plots was 0.75 m and between blocks was 1.5 m. The plot size was 4 m x 2.5 m. It is mentioned here that the wheat was sown maintaining row spacing as 20 cm. The seeds were sown as continuous in each line following 1.25 kg seed ha^{-}

3.9 Details of the field operations

The cultural operations were carried out during the experimentation are presented below:

3.9.1 Land preparation

The experimental field was first ploughed on November 01, 2008. The land was ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilth. The clods of the land were hammered to make the soil into small pieces. Weeds, stubbles and crop residues were cleaned from the land. The final ploughing and land preparation was done on November 13, 2008. The layout was done as per experimental design on November 13, 2008.

3.9.2 Fertilizer application

The entire amount of TSP (180kg ha^{-1}), MOP (50kg ha^{-1}) and Zypsum (120kg ha^{-1}) was given in the plots during final land preparation. Two-third of urea was applied for wheat plots during land preparation as basal except treatment 7 and 8 as those were given super granular urea (USG). Rest 1/3 urea was applied to wheat plots except treatment 7 & 8 at crown root initiation stage (21 DAS) followed by irrigation. The USG was given at the rate of 100 kg $ha\text{-}^{1}$

3.9.3 Seed collection and sowing

The wheat seeds (cv. Shourav) were collected from Wheat Research Centre of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

Seeds were treated with Vitavax 200 @ the rate of 3 g kg^{-1} of seeds and sown in line on November 14, 2008 and seeds were covered with loose friable soil.

3.9.4 Germination test

Germination test was performed before sowing the seeds in the field. Filter papers were placed on four petridishes and the papers were soaked with water where 100 seeds were placed at random in each petridish. Data on germination were determined as percentage basis by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds set for germination}} \times 100$$

3.9.5 Weeding

Weeds were controlled through three weeding at 20, 35, 50 days after sowing (DAS). The weeds identified were Kakpaya ghash (*Dactyloctenium aegyptium* L), Shama (*Echinocloa crussgalli*), Durba (*Cynodon dactylon*), Arail (*Leersis hexandera*), Mutha (*Cyperus rotundus* L), Bathua (*Chenopodiunm album*), Shaknatey (*Amaranthus viridis*), Foska begun (*Physalis beteophylls*), Titabegun (*Solanum torvum*) and Shetlomi (*Gnaphalium luteolabum* L).

3.9.6 Irrigation

Germination of seeds was ensured by light irrigation. Two irrigations were given in the crop at crown root initiation (21 DAS) and heading stages (53 DAS). During irrigation care was taken so that water could not flow from one plot to another or overflow the boundary of the plots. Excess water of the field was drained out.

3.9.7 Harvesting and sampling

At full maturity, the wheat crops were harvested plot wise on 9 March 2009. Before harvesting 10 plants of wheat from each plot was selected randomly and uprooted. Those were marked with tags, brought to the threshing floor where yield components were separated, cleaned and dried under sun for 4 consecutive days. Crop of each plot was harvested from 3 m^2 separately. Then those were weighted to record the grain yield and straw yield which were converted into t ha^{-1}.

3.10 Recording of data

The following data were collected during the study period:

1. Plant height from 15 DAS to harvest
2. Above ground dry matter plant $^{-1}$ from 15 DAS to harvest
3. Tillers $plant^{-1}$ from 30 DAS to harvest
4. Length of spike from 60 DAS to harvest
5. Spikelet $spike^{-1}$ from 60 DAS to harvest
6. 1000 grain weight (g)
7. Grain yield (t ha^{-1})
8. Straw yield (t ha^{-1})
9. Biological yield (t ha^{-1})
10. Harvest index (%)

3.11 Procedure of recording data

The data was taken at 15 days interval. The detail outline of data recording is given below:

3.11.1 Plant height (cm)

For height measurement 10 randomly plants were used from the ground level to tip of the plants and than averaged.

3.11.2 Above ground dry matter plant^{-1} (g plant^{-1})

Ten plants were collected at 15, 30, 45, 60, 75, 90 DAS and at harvest and then oven dried at 70^0 C for 72 hours. The dried samples were then weighed and averaged.

3.11.3 Tillers plant^{-1} (No.)

Ten plants were uprooted randomly and then total numbers of tillers were divided by 10.

3.11.4 Length of spike (cm)

Lengths of spike were measured from 10 plants and then averaged.

3.11.5 Spikelet spike $^{-1}$ (No.)

The numbers of spikelet spike^{-1} were measured from 20 spikes.

3.11.6 Weight of thousand grain (g)

Thousand cleaned dried grains were counted randomly from each harvested sample and weighed by using digital electric balance.

3.11.7 Grain yield (t ha^{-1})

Wheat was harvested randomly from 3 m^2 area of each plot. Then the harvested wheat was threshed, cleaned and then sun dried up to 12% moisture level. The dried seeds were then weighted and averaged. The grain yield was converted into t ha^{-1}.

3.11.8 Harvest Index (%)

Harvest index was determined by dividing the economic yield (grain yield) to the biological yield (grain + straw yield) from the same area and then multiplied by 100.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (t ha}^{-1})}{\text{Grain yield (t ha}^{-1}) + \text{straw yield (t ha}^{-1})} \text{ X } 100$$

3.12 Economic analysis

The cost and return analysis was done for each treatment on per hectare basis.

3.13 Benefit-cost ratio (BCR)

In order to compare better performance, benefit – cost ratio (BCR) was calculated. BCR value was computed from the total cost of production and net return according to the following formula:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (Tk. ha}^{-1})}{\text{Total cost of production (Tk. ha}^{-1})}$$

3.14 Statistical analysis

Plot wise yield and yield components were recorded. All the data were statistically analyzed following the MSTATC computer program and the mean comparisons were made by Least Significant Difference (LSD) test.

Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

This experiment was conducted to determine the response of wheat to different placement of urea. Data on plant growth characters, yield contributing characters and yield were recorded to asses the trend of growth, and yield of wheat under different methods of placement of urea fertilizer. The analysis of variance (ANOVA) of data is given in Appendices. The results have been presented and discussed under the following headings:

4.1Growth attributes of wheat

4.1.1 Plant height

Plant height of wheat increased with the advancement of plant age, starting slowly from early growth cycle than rapidly from 60 DAS. That persisted till The plant height was found non significant at all growth stages under different managements of urea (Fig. 1 and Appendix II).

At 15 DAS, numerically maximum plant height (25.13 cm) was obtained from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment and the minimum (21.62cm) from T_3 treatment (Prilled urea placed between two rows of wheat).

At 30 DAS, maximum plant height (42.23 cm) was obtained from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) and the minimum (37.50 cm) was obtained from T_5 (Line sown seed + line placed prilled urea) treatment.

At 45 DAS, Maximum plant height (54.77cm) was recorded from treatment T_8 (USG placed in between two wheat lines at 8 cm distance) and the minimum value (47.70 cm) was obtained from T_3 (Prilled urea placed between two rows of wheat) treatment. Tallest plant (77.67 cm) was recorded from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment and the shortest plant was recorded from T_1 (Prilled urea broadcasted) treatment at 60 DAS.

At 75 and 90 DAS the higher plant height 79.13 cm and 80.88 cm were obtained from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) whereas lower plant height 72.47 cm and 74.07 cm were obtained from T_1 (Prilled urea broadcasted) treatment.

At harvest, the tallest plant 82.97 cm was noted where USG placed in between two wheat lines at 8 cm distance (T_8) and the shortest (76.48 cm) from T_3 (Prilled urea placed between two rows of wheat) treatment.

Masum, (2008) reported that initially there was no significant effect of USG on plant hight but on later stage there was a significant effect of USG. It might be due to continuous availability of N from the deep placed USG that released N slowly and it enhanced growth of crop. Similar results were found by Singh and Singh (1986). They reported that USG produced taller plants than prilled urea.

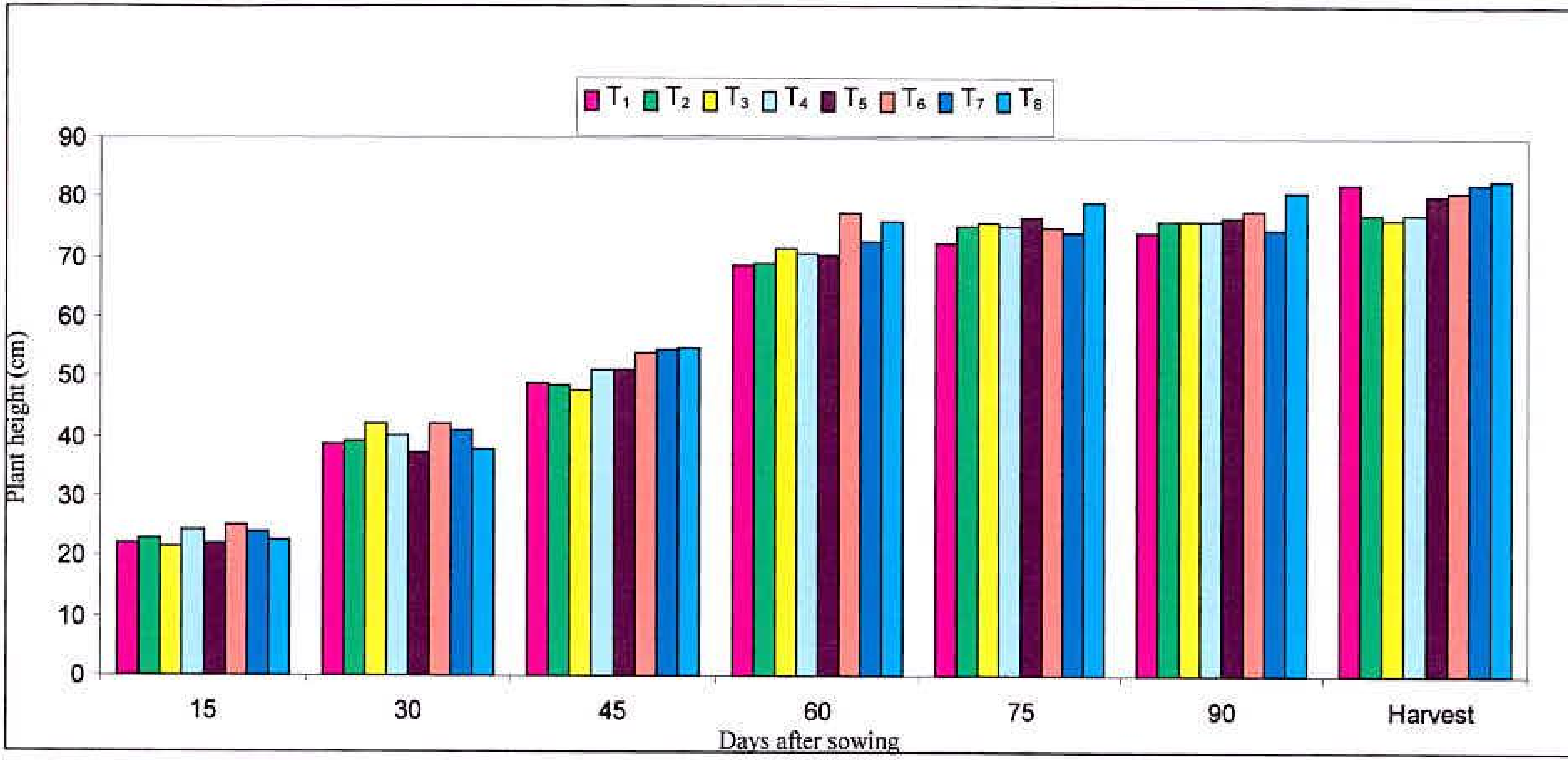

Figure 1: Plant height of wheat at different days under different managements of urea ($LSD_{0.05}$ = NS, NS, NS, NS, NS, NS and NS at 15, 30, 45, 60, 75, 90 DAS and harvest, respectively)

T_1 = Prilled urea broadcasted (conventional), T_2 = Prilled urea placed in furrow, T_3 = Prilled urea placed between two rows of wheat,
T_4 = Prilled urea + seed in furrow, T_5 = Line sown seed + line placed prilled urea, T_6 = Line sown seed + Prilled urea given on soil of seeded furrow,
T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance, T_8 = USG placed in between two wheat lines at 8 cm distance.
NS = Not Significant

4.1.2 Dry matter plant^{-1}

The above ground dry matter was not significantly affected due to different methods of urea fertilizer placement (Table 1 and Appendix III). Numerically some differences were observed.

At 15 DAS, the higher dry matter of wheat (0.07 g plant^{-1}) was obtained from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) and the lower dry matter (0.055 g plant^{-1}) was obtained from T_3 (Prilled urea placed between two rows of wheat).

At 30 DAS, the maximum dry matter weight of wheat (0.54 g plant^{-1}) was obtained from T_1 (Prilled urea broadcasted) treatment and the dry matter (0.37 g plant^{-1}) from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment.

At 45 DAS, the maximum dry weight of wheat was obtained from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) and the minimum from T_5 (Line sown seed + line placed prilled urea) treatment.

At 60 DAS, the higher dry matter weight of wheat (4.29 g plant^{-1}) was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment. The lower dry matter (3.13 g) was obtained from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment.

At 75 DAS, the maximum dry weight of wheat 4.92 g plant^{-1} was obtained from T_5 (Line sown seed + line placed prilled urea) treatment and the minimum (3.43 gplant^{-1}) from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment.

At 90 DAS, the higher dry matter (6.76 g plant^{-1}) was recorded from treatment Prilled urea broadcasted (T_1). The lower (4.54 g plant^{-1}) from T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment.

At maturity, maximum dry matter of wheat 8.79 g $plant^{-1}$ was obtained from T_1 (Prilled urea broadcasted) treatment and the minimum dry matter (6.66 g) from T_4 (Prilled urea + seed in furrow) treatment.

Rambabu *et al.* (1983) and Rao *et al.* (1986) reported from their study that USG was the most effective in increasing total dry matter than split application of urea.

Table 1: Above ground dry matter accumulation of wheat plant at different days under different managements of urea fertilizer

Particulars	Above ground dry matter (g plant^{-1}) at different days after sowing(DAS)						
Treatment	**15**	**30**	**45**	**60**	**75**	**90**	**At harvest**
T_1	0.07	0.55	1.73	3.30	4.61	6.76	8.80
T_2	0.06	0.40	1.73	4.00	4.49	5.98	6.75
T_3	0.06	0.43	1.42	3.24	4.35	5.26	6.72
T_4	0.06	0.42	1.63	3.47	4.92	5.79	6.66
T_5	0.07	0.39	1.14	3.81	4.92	5.91	7.02
T_6	0.08	0.53	1.92	3.13	3.53	4.55	6.77
T_7	0.07	0.45	1.85	3.75	4.64	6.21	7.26
T_8	0.07	0.37	1.52	4.29	3.44	5.55	7.50
$LSD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV%	**12.56**	**13.58**	**11.13**	**14.34**	**14.68**	**13.27**	**10.78**

NS = Not Significant.

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance and

4.2 Yield attributes of wheat

4.2.1 Tillers plant^{-1}

Tillers plant^{-1} was found to be significant only at 60 DAS and harvest due to variation of urea fertilizer management (Table 2 and Appendix IV).

At 30 DAS, numerically the higher number of tillers plant^{-1} of wheat (2.53) was obtained from T_1 (Prilled urea broadcasted) and the lower number of tillers plant^{-1} from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment.

At 45 DAS, the maximum number of tillers plant^{-1} of wheat (3.0) was obtained from T_1 (Prilled urea broadcasted) and the minimum number of tillers plant^{-1} (1.33) was obtained from T_4 (Prilled urea + seed in furrow) treatment.

At 60 DAS, significantly the highest number of tillers plant^{-1} of wheat (3.0) was obtained from T_1 (Prilled urea broadcasted) and T_5 (Line sown seed + line placed prilled urea) treatment. The lowest number of tillers plant^{-1} (1.33) was obtained from T_4 (Prilled urea + seed in furrow) treatment and it was statistically identical with T_2 (Prilled urea placed in furrow) treatment and T_8 (USG placed in between two wheat lines at 8 cm distance).

At 75 DAS, numerically maximum tillers plant^{-1} of wheat (3.067) was reordered from T_1 (Prilled urea broadcasted) treatment and the minimum (1.66) from T_4 (Prilled urea + seed in furrow) treatments.

At 90 DAS, numerically the higher (3.53) number of tillers plant^{-1} of wheat was recorded from T_1 (Prilled urea broadcasted). The lower number of tillers plant^{-1} (2.20) was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance).

At harvest, significantly highest (3.76) number of tillers plant^{-1} was obtained from T_1 (Prilled urea broadcasted) treatment and the lowest (1.93) from T_4 (Prilled urea + seed in furrow) treatments. The result indicated Prilled urea increased the number of tillers than USG. Similar results were found by Peng *et al.* (1996) and Schneir *et al.* (1990). They reported that N supply controlled the tiller production of rice plant unless other factors such as spacing or light become limited.

Table 2: Tillers of wheat plant at different days after sawing (DAS) under different placement of urea fertilizer

Treatment	Number of tillers $plant^{-1}$ at different days					
	30	**45**	**60**	**75**	**90**	**At harvest**
T_1	2.53	3.00	3.00	3.07	3.53	3.76
T_2	1.90	2.00	2.00	2.47	2.57	2.79
T_3	1.70	2.00	2.33	2.53	2.97	3.35
T_4	1.53	1.33	1.33	1.67	2.70	1.93
T_5	2.33	2.33	3.00	2.80	2.90	3.57
T_6	1.67	2.00	2.43	2.40	2.46	2.50
T_7	2.00	2.33	2.67	2.80	3.27	3.57
T_8	1.50	1.60	1.82	1.93	2.20	2.33
$LSD_{0.05}$	**NS**	**NS**	**0.77**	**NS**	**NS**	**0.97**
CV%	**10.13**	**15.05**	**14.06**	**14.80**	**13.97**	**13.52**

NS = Not Significant

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance and

4.2.2 Length of spike (cm)

The length of spike of wheat varied significantly only at 60 DAS due to different methods of urea fertilizer placement (Table 3 and Appendix V). The longest spike of wheat (13.73 cm) was recorded with T_5 treatment (Line sown seed + line placed prilled urea) and the minimum (11.93 cm) from T_7 treatment (Wheat seed + urea super granule in the same furrow at 8cm distance) at 60 DAS.

Longest spike 13.09 cm at 75 DAS, 14.4 cm at 90 DAS and 14.98 cm at harvest were obtained from T_1 (Prilled urea broadcasted) treatment and the smallest (12.28 cm and 75 DAS, 12.83 cm at 90 DAS and 12.98 cm at harvest) from T_7 (Wheat seed + urea super granule in the same furrow at 8cm distance) treatment.

Table 3: Spike length (cm) of wheat at different days as influenced by urea fertilizer placement

Treatment	Spike length (cm) at different days after sowing			
	60	75	90	At harvest
T_1	13.67	13.09	14.47	14.98
T_2	12.49	12.31	13.77	14.86
T_3	12.11	12.89	14.29	14.88
T_4	11.96	12.70	14.05	14.75
T_5	13.73	13.77	13.87	14.79
T_6	12.13	12.31	13.51	14.59
T_7	11.93	12.28	12.83	12.98
T_8	12.37	12.45	14.22	14.76
$LSD_{0.05}$	**1.27**	**NS**	**NS**	**NS**
CV%	**5.76**	**5.19**	**5.94**	**5.06**

NS = Not Significant.

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance and

4.2.3 Spikelet spike^{-1}

Number of spikelet spike^{-1} of wheat at different days as influenced by different methods of urea fertilizer placement except at harvest (Table 4 and Appendix VI). At 60 DAS, the highest number of spikelet spike^{-1} (15.91) was obtained from T_1 (Prilled urea broadcasted) treatment. The lowest number of spikelet spike^{-1} (13.20) was obtained from T_7 (Wheat seed + urea super granule (USG) in the same furrow at 8cm distance) treatment which was statistically identical with T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment and T_8 (USG placed in between two wheat lines at 8 cm distance) treatment.

At 75 DAS, the highest number of spikelet spike^{-1} of wheat (16.267) was shown in T_3 (Prilled urea placed between two rows of wheat) treatment and it was stasitically identical with T_1 (Prilled urea broadcasted) treatment. The lowest number of spikelet spike^{-1} of wheat (13.46) was shown in T_7 (Wheat seed + urea super granule (USG) in the same furrow at 8cm distance) and it was similar with T_2 (Prilled urea placed in furrow) treatment, and T_8 (USG placed in between two wheat lines at 8 cm distance) treatment.

At 90 DAS, the highest (16.30) number of spikelet spike^{-1} was obtained from T_3 (Prilled urea placed between two rows of wheat) treatment and it was statistically identical with T_1 (Prilled urea broadcasted) and T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment. The lowest number of spikelet spike^{-1} of wheat (15.32) was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment.

At harvest, numerically higher number of spikelet spike^{-1} (16.69) was noted in T_5 (Line sown seed + line placed prilled urea) treatment and the lowest (14.83) from T_7 (Wheat seed + urea super granule in the same furrow at 8cm distance) treatment.

Table 4: Spikelet spike^{-1} of wheat at different days as influenced by urea fertilizer placement

Treatment	Spikelet spike^{-1} at different days after sowing			
	60	**75**	**90**	**At harvest**
T_1	15.91	16.12	16.21	16.50
T_2	13.54	14.26	15.73	15.93
T_3	14.82	16.27	16.30	16.30
T_4	15.07	15.27	15.72	16.37
T_5	13.03	14.91	15.05	16.69
T_6	13.56	15.59	16.06	16.46
T_7	13.20	13.46	14.77	14.88
T_8	13.74	14.22	15.32	15.91
$LSD_{0.05}$	**2.82**	**2.14**	**1.79**	**NS**
CV%	**10.16**	**8.01**	**7.20**	**9.05**

NS = Not Significant.

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance and

4.2.4 Thousand grain weight

There was significant variation in thousand grain weight due to different managements of Nitrogen (Table 5 and Appendix VII). Maximum thousand grain weight (39.27 g) of wheat was recorded from treatment were Line sown seed + Prilled urea given on soil of seeded furrow (T_6) followed by T_2 and T_7 treatments. The lowest grain weight (36.43 g) was found with T_4 (Prilled urea + seed in furrow). In case of rice, 1000 - grain weight is more or less stable genetic character (Yoshida, 1981) and nitrogen management strategy could not increase the grain weight.

Table 5: Thousand grain weight of wheat as influenced by different placement of urea fertilizer

Treatment	1000 grain wt. (g)
T_1	37.12
T_2	39.09
T_3	37.47
T_4	36.43
T_5	37.10
T_6	39.27
T_7	38.60
T_8	37.61
$LSD_{0.05}$	**1.70**
CV%	**6.22**

NS = Not Significant

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance and

4.2.5 Grain yield

Grain yield ha^{-1} of wheat was affected significantly by the different methods of urea fertilizer placement (Table 6 and Appendix VII). It varied from 2.43 to 3.11 t ha^{-1}. The highest grain yield (3.11 t ha^{-1}) of wheat was obtained from T_8, USG placed in between two wheat lines at 8 cm distance, which indicates the superiority of urea super granules over prilled urea and the lowest (2.43 t ha^{-1}) from T_4 (Prilled urea + seed in furrow) treatment. Placement of Nitrogen fertilizer in the form of urea super granules gave 16.5% more yield than the broadcasted urea. Similar finding was obtained from BRRI (2000) and they found that USG gave 18% yield increase over the recommended prilled urea.

Similar results were also found by Mishra *et al.* (2000) and Raju *et al.* (1987) who observed that among all forms of N, urea super granules recorded the highest grain yield and proved significantly superior to other sources. Haque, (2002) also showed that point placement of urea super granules greatly increased yield of potato tubers.

As urea super granule is a slow release nitrogenous fertilizer which dissolves slowly in the soil providing a steady supply of available nitrogen throughout the growing period of crop. Probably due to this reason the plant got enough nutrients for its growth of development and that's why urea super granules treated plots influenced favorably as reflected in the increased in number of grain spike, 1000 grains that initially resulted in greater yield than prilled urea.

4.2.6 Straw yield

The highest straw yield ha^{-1} was observed in T_1 (Prilled urea broadcasted) treatment and the lowest straw yield was observed in T_6 (Line sown seed + Prilled urea given on soil of seeded furrow) treatment, (Table 6 and Appendix VIII). However, urea supergranules produced comparatively less straw yield as that has been partitioned into seed.

4.2.7 Biological yield

Biological yield was significantly affected by the forms of nitrogen fertilizer. Biological yield varied from 6.18 to 7.44 t ha^{-1}. Maximum biological yield (7.44 t ha^{-1}) was observed from the urea super granules treated plot than prilled urea (Table 6 and Appendix IX).

4.3 Harvest Index

Harvest Index (HI) of wheat was varied non significantly due to different methods of urea fertilizer placement (Table 6 and Appendix X). Harvest index describe the degree of dry matter partitioning to the economically important part of the plant. However, HI was generally low which varied between 36.93 and 41.80% regardless of treatments. The highest (41.80 %) harvest index was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance) and the lowest (36.93 %) from T_1 (Prilled urea broadcasted) treatment. Ali (2005) reported that N management strategy did not influence HI. Miah *et al.* (2004) also reported that forms of nitrogen fertilizer had exerted very little variation on harvest index. Yield potentiality was higher in T_8 treatment than others. HI was higher in T_8 treatment indicating favorable partitioning of the dry matter towards the production of economic yield. Lesser HI suggests relatively lesser translocation of assimilates for grain development.

Table 6: Grain, straw, biological yield and harvest index of wheat as influenced by different methods of urea fertilizer placement

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
T_1	2.67	4.56	7.23	36.93
T_2	2.63	4.43	7.06	37.25
T_3	2.54	3.78	6.32	40.18
T_4	2.43	3.75	6.18	39.32
T_5	2.68	4.10	6.78	39.53
T_6	2.78	4.07	6.85	40.58
T_7	2.89	4.17	7.06	40.93
T_8	3.11	4.33	7.44	41.80
$LSD_{0.05}$	**0.87**	**0.46**	**0.48**	**NS**
CV%	**11.77**	**6.33**	**3.99**	**6.00**

NS = Not Significant

T_1 = Prilled urea broadcasted (conventional)

T_2 = Prilled urea placed in furrow

T_3 = Prilled urea placed between two rows of wheat

T_4 = Prilled urea + seed in furrow

T_5 = Line sown seed + line placed prilled urea

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance

T_8 = USG placed in between two wheat lines at 8 cm distance and

4.4 Economic evaluation

4.4.1 Total variable cost

Marked variation in total variable cost was observed among the treatments (Table 6). The highest variable cost Tk. 44686 ha^{-1} was obtained from T_7 (Wheat seed + urea super granule in the same furrow at 8cm distance) and T_8 (USG placed in between two wheat lines at 8 cm distance) treatment. The lowest variable cost of Tk. 43006 ha^{-1} was recorded from T_1 (Prilled urea broadcasted).

4.4.2 Gross return

Gross return was affected by different management of urea (Table 6). The highest gross return of Tk.55310 ha^{-1} was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance) treatment and the lowest (Tk.43950 ha^{-1}) was obtained from T_4 (Prilled urea + seed in furrow) treatment.

Hussain *et al.* (2010) reported that though higher cost was involved in USG practice and 10% less USG than recommended dose in comparison with prilled urea, the highest gross margin (Tk.117588 ha^{-1}) was obtained from the recommended dose of N as USG among the treatments.

4.4.3 Net return

The highest net return of Tk. 10624 ha^{-1} over variable cost was obtained from treatment were USG placed in between two wheat lines at 8 cm distance (Table 6). The second highest value (Tk. 7004 ha^{-1}) was obtained from T_7 (Wheat seed + urea super granule in the same furrow at 8cm distance) treatment and the lowest (Tk. 944 ha^{-1}) from T_4 (Prilled urea + seed in furrow) treatment.

4.4 Benefit cost ratio

Benefit cost ratio was affected by different management of urea (Table 6). When benefit-cost ratio of each treatment was examined it was found that T_8 (USG placed in between two wheat lines at 8 cm distance) treatment gave the highest benefit cost ratio (1.24). The cost and return analysis indicated that treatment T_8 gave the maximum gross return, net return and benefit cost ratio.

Table 7: Economic analysis of wheat due to different methods of urea fertilizer placement

Treatments	Total variable cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	Benefit cost ratio (BCR)
T_1	43006	49170	6164	1.14
T_2	44126	48310	4184	1.09
T_3	44462	45660	1198	1.02
T_4	43006	43950	944	1.02
T_5	43566	48400	4834	1.11
T_6	43566	49840	6274	1.14
T_7	44686	51690	7004	1.16
T_8	44686	55310	10624	1.24

Price rate: Wheat seed Tk. 15 kg^{-1}.Variable cost includes cost of fertilizer, irrigation, labour, seeds etc. Benefit cost ratio is based on the total variable cost only.

T_1 = Prilled urea broadcasted (conventional) ,

T_2 = Prilled urea placed in furrow,

T_3 = Prilled urea placed between two rows of wheat,

T_4 = Prilled urea + seed in furrow,

T_5 = Line sown seed + line placed prilled urea,

T_6 = Line sown seed + Prilled urea given on soil of seeded furrow,

T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8cm distance,

T_8 = USG placed in between two wheat lines at 8 cm distance.

Chapter 5
Summary and Conclusion

SUMMARY AND CONCLUSION

An experiment was conducted at the research field of Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 11, 2008 to March 09, 2009 to study the response of wheat to different placement of urea fertilizer. Eight treatment combinations were: T_1 = Prilled Urea broadcasted (conventional), T_2 = Prilled Urea placed in furrow, T_3 =Prilled urea placed between two rows of wheat, T_4 = Prilled urea + seed in furrow, T_5 = Line sown seed + line placed prilled urea, T_6 = Line sown seed + prilled urea given on soil of seeded furrow, T_7 = Wheat seed + urea super granule (USG) in the same furrow at 8 cm distance and T_8 = USG placed in between two wheat lines at 8 cm distance. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications.. The recommended seed rate of wheat was 125 kg ha^{-1}. Seeds of this crop (cv. Shourav) were sown on November 14, 2009 and harvested on March 09, 2009. The total number of plots was 24 and the size of the unit plot was 4m X 2.5m.

The data on plant height, above ground dry matter, number of tillers $plant^{-1}$, spike length, spikelet $spike^{-1}$, 1000 grain weight g^{-1}, straw yield ha^{-1} and harvest index were recorded.

At maturity, tallest plant (82.97 cm) of wheat was obtained from T_8 (USG placed in between two wheat lines at 8 cm distance) and the smallest plan (77.15 cm) from T_3 (Prilled Urea placed between two rows of wheat) treatments. Largest (14.48 cm) spike of wheat at harvest was recorded from T_1 (Prilled Urea broadcasted) treatments and shortest (12.98 cm) from T_7 (Wheat seed + urea super granule in the same furrow at 8cm distance) treatments.

Higher number of spikelet $spike^{-1}$ (16.69) was counted from T_5 (Line sown seed + line placed prilled urea) and the lower one (14.83) from T_7 (Wheat seed + urea super granule in the same furrow at 8cm distance) treatment.

Highest grain yield (3.11t ha^{-1}) was obtained from treatment where USG placed in between two wheat lines at 8 cm distance treatment (T_8). The result revealed that urea super granules gave 16.5% more yield over prilled urea in broadcasting system.

On the contrary, T_8 (USG placed in between two wheat lines at 8 cm distance) treatment gave lower straw yield as its dry matter was partitioned into seed which indicated by higher value of harvest index (41.80%).

The highest gross return (Tk. 553109 ha^{-1}), net return (Tk. 10624 ha^{-1}) and benefit cost ratio of 1.24 were obtained from T_8 treatment USG placed in between two wheat lines at 8 cm distance. The second highest gross return (Tk. 51690 ha^{-1}), net return (Tk. 7004 ha^{-1}) and benefit cost ratio (1.16) were obtained from T_7 (Wheat seed + urea super granules in the same furrow at 8cm distance) treatment. The lowest gross return (tk. 43450 ha^{-1}), net return (tk. 944 ha^{-1}) and benefit cost ratio (1.02) were obtained from T_4 (Prilled urea + seed in furrow) treatment.

The results of the experiment thus revealed that USG placed in between two wheat lines at 8 cm distance gave high grain yield, biological yield, harvest index and benefit cost ratio among the treatments.

Point placement technology of fertilizers is a new approach in increasing yield of crops with use of lesser amount of fertilizer. It saves fertilizer to a great extent through reduction of its uses because of increased agronomic efficiency and it is environmentally friendly since, the effect on environmental pollution is greatly minimized.

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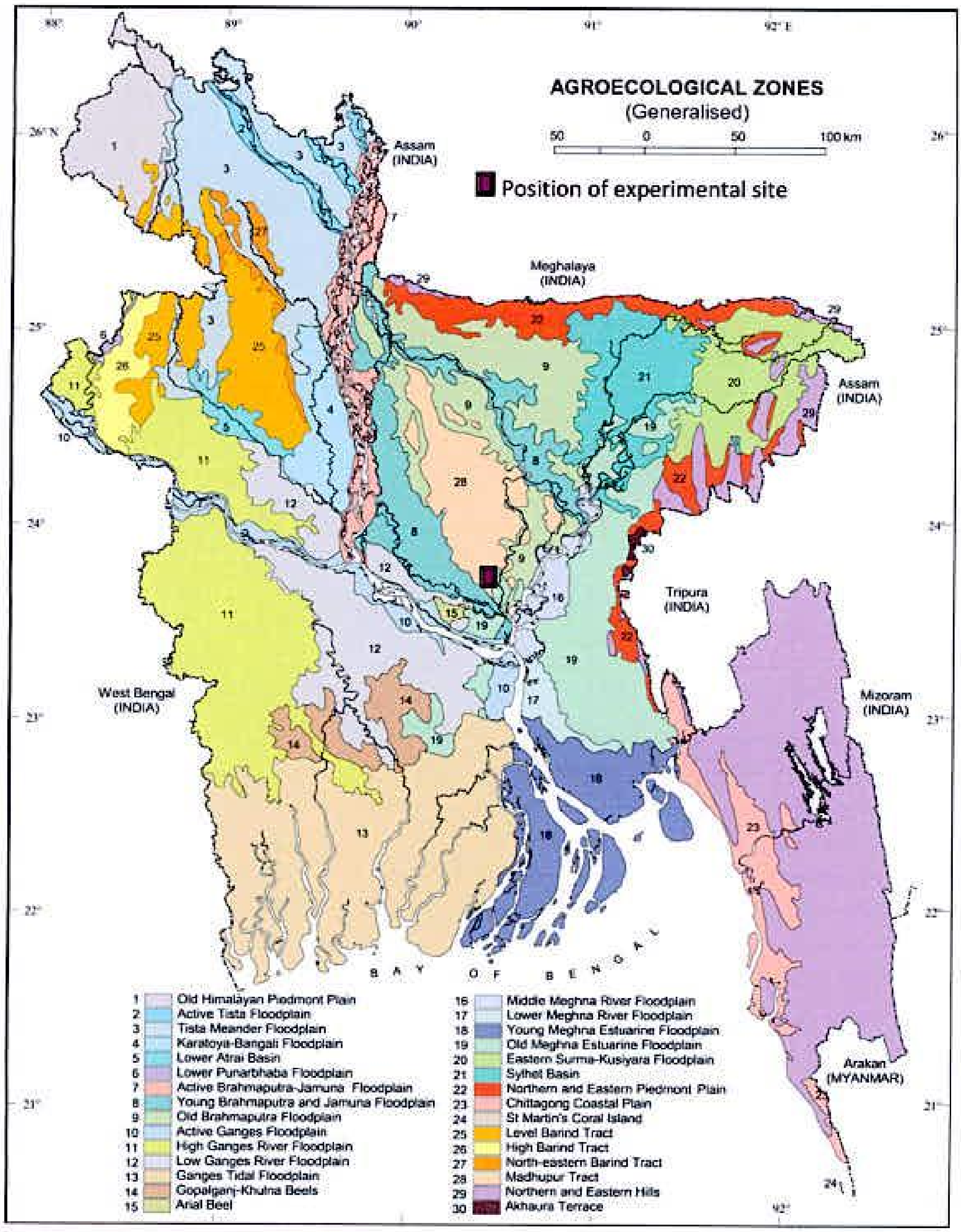
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II: ANOVA for plant height of wheat

Sources of variation	Degrees of Freedom	Error Mean Square						
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
Replication	2	2.72	1.19	0.14	0.61	3.64	0.68	1.96
Treatment	7	1.73^{NS}	1.19^{NS}	0.89^{NS}	1.23^{NS}	1.95^{NS}	0.55^{NS}	2.06^{NS}
Error	14	2.73	8.43	26.88	24.97	5.68	24.09	10.03
Total	23							

^{NS} = Non significant

Appendix III: ANOVA for above ground dry matter plant^{-1} of wheat

Sources of variation	Degrees of Freedom	Error Mean Square						
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
Replication	2	0.59	3.72	1.04	10.14	2.86	0.53	0.29
Treatment	7	0.65^{NS}	0.63^{NS}	0.91^{NS}	0.63^{NS}	1.23^{NS}	1.69^{NS}	2.57^{NS}
Error	14	0.001	0.021	0.21	0.78	0.81	0.77	0.60
Total	23							

^{NS} = Non significant

Appendix IV: ANOVA for tillers plant^{-1} of wheat

Sources of variation	Degrees of Freedom	Error Mean Square					
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
Replication	2	4.88	0.42	3.04	1.12	0.53	3.06
Treatment	7	1.59^{NS}	1.73^{NS}	5.22**	1.61^{NS}	1.47^{NS}	4.53**
Error	14	0.26	0.44	0.19	0.40	0.39	0.30
Total	23						

^{NS} = Non significant

** = Significant at 1% level

Appendix V: ANOVA for spike length of wheat

Sources of variation	Degrees of Freedom	Error Mean Square			
		60 DAS	75 DAS	90 DAS	At harvest
Replication	2	2.14	9.32	5.81	0.72
Treatment	7	2.99*	0.79^{NS}	1.20^{NS}	2.36^{NS}
Error	14	0.52	0.42	0.68	0.54
Total	23				

^{NS} = Non significant

* = Significant at 5% level

Appendix VI: ANOVA for spikelet spike^{-1} of wheat

Sources of variation	Degrees of Freedom	Error Mean Square			
		60 DAS	75 DAS	90 DAS	At harvest
Replication	2	3.17	4.35	4.63	0.53
Treatment	7	1.79*	2.91*	3.32*	0.51^{NS}
Error	14	2.59	1.49	1.05	2.05
Total	23				

^{NS} = Non significant

* = Significant at 5% level

Appendix VII: ANOVA for grain yield and 1000 seed weight of wheat

Sources of variation	Degrees of Freedom	Error Mean Square	
		Grain yield	1000 seed weight
Replication	2	1.46	1.12
Treatment	7	1.7188*	2.52**
Error	14	0.24	5.46
Total	23		

* = Significant at 5% level

** = Significant at 1% level

Appendix VIII: ANOVA for straw yield of wheat

Sources of variation	Degrees of Freedom	Error Mean Square
		Straw yield
Replication	2	0.026
Treatment	7	0.249*
Error	14	0.069
Total	23	

* = Significant at 5% level

Appendix IX: ANOVA for biological yield of wheat

Sources of variation	Degrees of Freedom	Error Mean Square
		Biological yield
Replication	2	0.08
Treatment	7	0.56**
Error	14	0.08
Total	23	

** = Significant at 1% level

Appendix X: ANOVA for harvest index of wheat

Sources of variation	Degrees of Freedom	Error Mean Square
		Harvest index
Replication	2	0.065
Treatment	7	9.13^{NS}
Error	14	5.65
Total	23	

^{NS}= Non significant

Appendix XI: Price list of Seed, Fertilizers and Irrigation

Particulars Name	Rate
Seed	40 $Tk.Kg^{-1}$
Irrigation	5000 $Tk.ha^{-1}$
Labour	112 $Tk.day^{-1}$
Urea	14 $Tk.Kg^{-1}$
TSP	40 $Tk.Kg^{-1}$
MP	35 $Tk.Kg^{-1}$
Zypsum	10 $Tk.Kg^{-1}$
USG	18 $Tk.Kg^{-1}$